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Random Wavelength Assignment using Normal Distribution in Wavelength Converted WDM Networks

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ABSTRACT
In this work, random assignment based on the normal distribution is modeled considering the wavelength conversion. The performance of the random assignment based on the normal distribution is compared with that of the random assignment based on the uniform distribution and first fit models. Two simulation cases are considered, one with 10 links and the other with 20 links. The results are presented. The performance of random assignment based on the normal distribution is superior to that of random assignment based on the uniform distribution and first fit models at most of the nodes.

Keywords
WDM, RWA, Random assignment, First fit assignment, conversion of wavelengths.

1. INTRODUCTION
Wavelength Division Multiplexing (WDM) is a technology of transmitting the light of different wavelengths through the same optical fiber [1,2]. The network is formed by connecting several optical fibers and each one is termed as a link. The links are connected to each other at nodes and the arbitrary topology can be formed by connecting them. A light path can be formed by sending a message from one node to another node in all the links from start node to the target node. In this method, the wavelength are not converted. The challenge lies in the selection of the path in the network, known as Routing, and assignment of the wavelength to the lighpath, known as Wavelength Assignment. The combined problems is popularly known as Routing and Wavelength Assignment (RWA) problem[3,4]. In this work the focus is made on the wave length assignment problem for a selected tandem network path.

There are three methods available for the wavelength assignment. They are:

1. First fit wavelength assignment [1,5-8]
2. Random wavelength assignment based on uniform distribution [1,5-8]
3. Random wavelength assignment based on normal distribution [9]

The first two models are well known and the last model, that is Random wavelength assignment based on normal distribution is proposed by the authors in ref [9]. The Random wavelength assignment based on normal distribution yields a similar performance to that of the first fit wavelength assignment. The Random wavelength assignment based on uniform distribution performance is very poor compared to that of first fit wavelength assignment. However first fit wavelength assignment lacks the flexibility of utilizing all the available channels uniformly and randomly other than assigning it only to first available free channels. Wavelength assignment based on uniform distribution overcomes this problem, but the performance is very poor since the blocking probabilities are very high. These two problems are overcome in the wavelength assignment based on normal distribution proposed by authors in ref [9]. The assignment models must satisfy the following conditions [1].

- Wavelength continuity constraint: The wavelength must be same on the entire path in all the links.
- Distinct wavelength constraint: If there are multiple lightpaths in one link, then all the lightpaths must have been assigned distinct wavelengths in that link.

If there is no common wavelength available in the entire path, then it results in blocking. This results in high blocking probabilities leading to call rejections or delays in the assignment. This problem can be overcome by the installing the wavelength converters at the nodes. When a call arrives at a node with a certain wavelength at next link, which was assigned at the start node, and there is no free channel available for that wavelength in the next link, then the wavelength of the call is converted by the converter and pushes it through the next link. The new wavelength will be based on the wavelengths available free channels in the next link. However, this method overrules the wavelength continuity constraint.

A wavelength converter may be defined as a device which is capable of converting one wavelength to another wavelength [10,11]. The cost associated with the wavelength converters is high, but cost is not given importance in this work since the aim is to reduce the blocking probabilities with the proposed method. In this work, first fit wavelength assignment, random wavelength assignment based on uniform distribution, and Random wavelength assignment based on normal distribution are modeled for blocking probabilities considering the conversion of the wavelengths. The proposed Random wavelength assignment based on normal distribution is proven to be the most effective model which yielded lowest blocking probabilities compared to other two models.

2. PROBABILITY MODEL

The assignment of wavelengths can be carried out using three methods, namely,

1. First fit assignment
2. Uniform distribution based random assignment
3. Normal distribution based random assignment

In the first fit model, the wavelengths are assigned to the call requests based on the first available free channel. For example, if the call request arrives and the first channel, if it is free, will be assigned to the call arrived. When the second call arrives, and if the first channel is not free, then the next free channel that is the second channel will be assigned. When a third call arrives, and if the first channel becomes free in the mean time and the second channel is still occupied, then the first channel is assigned. This process is repeated for all the call requests. The channels that are in the lower order are always given preference in the assignment and that are in the higher order are rarely assigned. When the holding times of the calls are larger, then the lower order channels become busy and the higher order channels start getting the assignment. When a call arrives, the wave length can be assigned to it based on the routing. For example, if it is a static routing, when a new call arrives, if any of the link is busy in the path identified for the channel identified, then another free channel path is to be chosen. This is the case with no-conversion of wavelength, if the channel must be free for the entire path to get the call assigned with that channel. Else, another free channel path is chosen. This is the requirement of the wavelength continuity constraint.

In uniform random assignment method, a random number based on the uniform distribution is generated and the random number is converted to a corresponding channel number in the link. When the fist call arrives, the channel is assigned based on the random number generated. It can be any channel in the link and not necessarily limited to the first channel. When the second call arrives, again a random number is generated and the corresponding channel is chosen for assignment. Since this is a uniform distribution based random assignment, the random numbers generated will usually be distinct each time the numbers are generated. Hence the second call is assigned to another channel. But when the number of call requests arrived are close to the number of channels, there is high probability that all the channels are occupied. This again depends upon the holding time of the calls. When the next call arrives, if the channel selected based on the random number is already occupied in that path, and no other free channel path is available, then the call gets blocked.

Authors have introduced a novel approach to control the assignment of channels irrespective of the order of the channels, yet based on the random assignment using normal distribution random number generation [9]. The model based on normal distribution based random assignment has proved to be a better model in terms of the blocking probabilities compared to the uniform distribution based random assignment and the performance was similar to that of the first fit model, but with the flexibility of having the random assignment and control over the index of the channel to be given preference. In normal distribution based random assignment, the random numbers are generated based on the normal distribution. Unlike the uniform distribution based random number generation, there is high probability that more number of random numbers are generated towards the mean and few are generated away from the mean. So is the case with the channels assigned. A particular channel or a set of channels are selected many times compared to the other channels. In other words, there is high probability that the same channel is selected for assignment consecutively or quite frequently. If the selected channel is busy, then another free channel is chosen. In case of first fit model, only the first channel in the order is given preference, and in the normal distribution based assignment, user has the option to choose any channel for preference. This can be achieved by selecting proper mean for the random number generator. Again the spread of the selected channels can be controlled through the selection of appropriate standard deviation. When the channel path is already occupied at any one link, and not other free channel paths are available then the call is said to be blocked.

In this work, a normal distribution based random assignment is carried out with the conversion of the wavelengths. That means the wavelength assigned to the call need not be same when transferring from one link to another link in the path. In this model, the channel is assigned if at least one channel is free in all the links. The channel in each link need not be same. For example, if there are three links in the path and each link having 3 channels, then no conversion requires, the first channel in all the link must be free for assignment or the second channel in all the links or the third channel in all the links must be free. In case of conversion model, if the channel 1 is free in link 1, channel 3 is free in link 2 and channel 2 is free in link 3, the assignment can be still be made, for example. The first channel is selected based on the normal distribution random numbers.

The blocking probability is calculated using

$$P_{blocking} = \frac{N_{block}}{N_{gen}} \quad \ldots (1)$$

where $P_{blocking}$ is the blocking probability, N_{block} is the number of calls blocked and N_{gen} is the number of calls generated. The blocking probability can be calculated using the in-famous Erlang B formula

$$P_{blocking}(L, C) = \frac{\frac{L^C}{C!}}{\sum_{j=0}^{C} \frac{L^j}{j!}}$$

(2)

where $P_{blocking}(L, C)$ is the blocking probability, L is the load and C is the number of channels or wavelengths.

3. SIMULATION RESULTS

In this section, the simulations were run for the cases for the blocking probability for two scenarios:

1. With NO WAVELENGTH CONVERSION
2. With WAVE LENGTH CONVERSION

Seven models were run for these two scenarios amounting to a total of 14 cases. The seven models are first fit assignment model, uniform distribution based random assignment model, and 5 normal distribution based random assignment model with means of 0.1, 0.2, 0.3, 0.4 and 0.5 respectively. In the normal distribution models, a standard deviation of 0.1 is used in all the 5 models.

Again two tandem network models are chosen to run these assignment model simulations. They are:

1. Load of 2 Erlangs per link with 10 Nodes and 7 channels on each link.
2. Load of 5 Erlangs per link with 20 Nodes and 11 channels on each link.

Each simulation is run for 2000 iterations to compute the blocking probabilities. All the simulation models that are run in this research work are presented in Table 1.

Table 1: Models used in the simulations

Model Name	Wavelength Conversion	Distribution used in Wavelength Assignment	Mean	Standard Deviation
FIRST FIT-NO CONV	NO	N.A.	N.A.	N.A.
UNIFORM -NO CONV	NO	Uniform	N.A.	N.A.
NORM 0.1-NO CONV	NO	Normal	0.1	0.1
NORM 0.2-NO CONV	NO	Normal	0.2	0.1
NORM 0.3-NO CONV	NO	Normal	0.3	0.1
NORM 0.4-NO CONV	NO	Normal	0.4	0.1
NORM 0.5-NO CONV	NO	Normal	0.5	0.1
FIRST FIT-NO CONV	YES	N.A.	N.A.	N.A.
UNIFORM -NO CONV	YES	Uniform	N.A.	N.A.
NORM 0.1-NO CONV	YES	Normal	0.1	0.1
NORM 0.2-NO CONV	YES	Normal	0.2	0.1
NORM 0.3-NO CONV	YES	Normal	0.3	0.1
NORM 0.4-NO CONV	YES	Normal	0.4	0.1
NORM 0.5-NO CONV	YES	Normal	0.5	0.1

Fig. 1 shows the blocking probability of First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models. These models were run on a tandem network having a load of 2 Erlangs per link and with 10 Nodes, 7 channels. The simulations were run for 2000 iterations and these simulations also considered the assignment with and without wavelength conversion. It can be observed that random assignment with no conversion based on uniform distribution random assignment has highest blocking probability compared to all other 13 models.

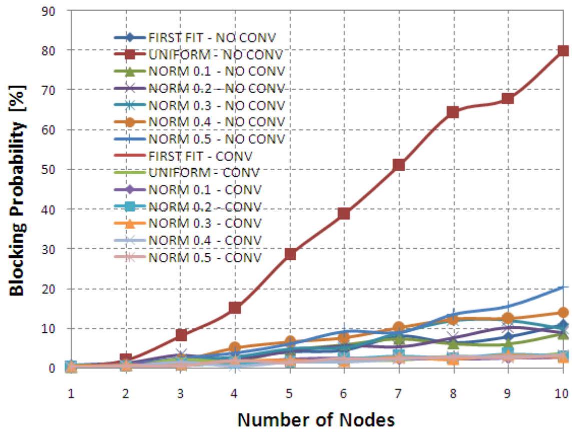

Figure 1: Blocking Probability of First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and without conversion

However, the blocking probability of uniform distribution random assignment reduces drastically when the wavelength conversion was considered. Table 2 shows the blocking probabilities of the 10 nodes that is presented in Fig.1, in tabular form.

Table 2: Total blocking probabilities [%] of the 10 nodes

2Er, 10 Nodes, 7 Chan	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
FIRST FIT - NO CONV	0.7	1.2	1.35	2.8	4.1	4.5	8	6.4	8	10.85
UNIFORM - NO CONV	0.25	2.05	8.15	15	28.45	38.75	50.95	64.25	67.95	79.95
NORM 0.1 - NO CONV	0.2	0.75	1.3	1.8	4.45	5.95	7.25	6.2	6	8.7
NORM 0.2 - NO CONV	0.2	1.2	3.25	2.2	4.2	5.65	5.3	7.65	10.3	8.9
NORM 0.3 - NO CONV	0.35	0.6	1.9	2.9	4.85	5.2	8.8	11.9	12.05	10
NORM 0.4 - NO CONV	0.15	1.1	1.95	5	6.55	7.55	10.1	12.3	12.4	14.1
NORM 0.5 - NO CONV	0.25	0.9	2.4	3.8	6	9.25	9	13.5	15.65	20.4
FIRST FIT - CONV	0.3	1	0.7	1.4	1.8	1.8	2.15	2.7	2.55	2.9
UNIFORM - CONV	0.7	0.55	2.15	1.55	1.9	2.3	2	3	2.65	3.75
NORM 0.1 - CONV	0.2	1.1	0.95	1.25	2.2	2.5	2.3	2.25	2.4	2.9
NORM 0.2 - CONV	0.15	0.6	0.7	1.3	1.5	2.25	2.95	2.6	3.5	3.1
NORM 0.3 - CONV	0.4	0.75	1	1.75	1.9	1.65	2.7	2.2	3.2	2.7
NORM 0.4 - CONV	0.2	0.5	1.55	0.45	1.4	1.6	2.3	2.9	2.75	3.4
NORM 0.5 - CONV	0.3	0.5	0.6	1.9	1.4	2.4	2.45	2.8	2.65	3.35

The cells in the table are marked in green that has the least blocking probability for each node and the ones marked in yellow are the next least for that node. It can be observed that normal distribution based random assignment models has least blocking probabilities for highest number of nodes. The first fit assignment model has not yielded the least blocking probability for any node when conversion was considered. The uniform distribution based random assignment models has least blocking probability with 2% only at the node 7.

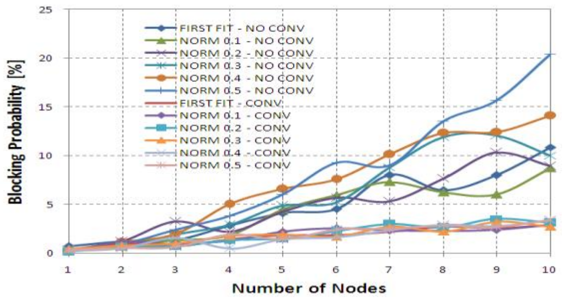

Figure 2: Blocking Probability of First Fit and 5 Normal Distribution based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and without conversion

Fig. 2 shows the blocking probability of First Fit and 5 Normal Distribution based Random Assignment models; and uniform distribution based random assignment model results are removed to get a good readability of the plot. It is very clear that the assignment with conversion yields better results compared to the no-conversion case. The no-conversion assignment models yield a maximum of 79.95% of blocking probability, and assignment models with conversion yield a maximum of 3.75% of blocking probability only. Hence the when conversion is considered the blocking probabilities are least.

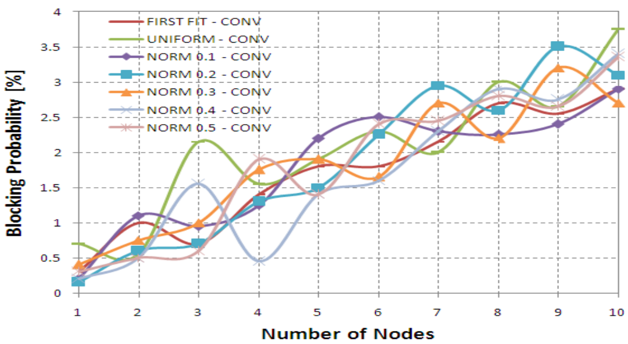

Figure 3: Blocking Probability of First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with conversion

Fig. 3 shows the blocking probability of First Fit and uniform distribution based random assignment and 5 Normal Distribution based Random Assignment models for assignment with wavelength conversion. The NORM 0.4 models yields the least blocking probabilities when wavelength conversion is considered at the nodes 1,2,5 and 6 which has performed consistently at a maximum of 4 nodes. The next highest performance was offered by NORM 0.5 model. The next least blocking probabilities are also offered by conversion assignment models compared to the non-conversion assignments.

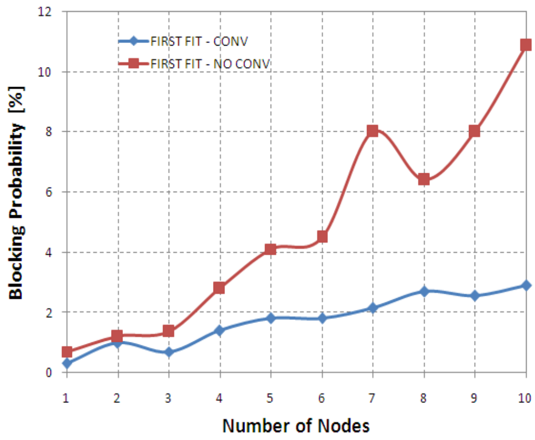

Figure 4: Blocking Probability of First Fit Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and without conversion

Fig. 4 shows the blocking probability of First Fit assignment models for assignment with (FIRST FIT-CONV) and without wavelength conversion (FIRST FIT- NO CONV). The blocking probabilities are better in the case with conversion assignment. In fact FIRST FIT-CONV is the second best for the nodes 3, 4, 7, 9, and 10 with blocking probabilities of 0.7, 1.4, 2.15, 2.55 and 2.9% respectively. The first best being the normal distribution based assignment models.

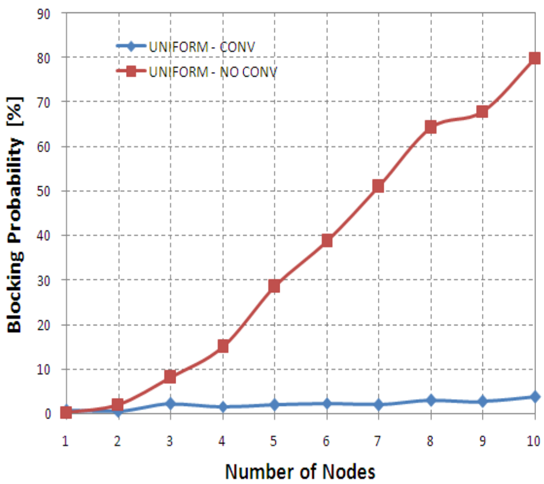

Figure 5: Blocking Probability of Uniform Distribution based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and withoutconversion

Fig. 5 shows the blocking probability of uniform distribution based random assignment models for assignment with (UNIFORM-CONV) and without wavelength conversion (UNIFORM-NO CONV). The blocking probabilities are better in the case with conversion assignment. The UNIFORM-CONV yielded best performance for the node 7 with blocking probabilities of 2 among all other models. However, similar performance was not exhibited by the UNIFORM-CONV model at other nodes.

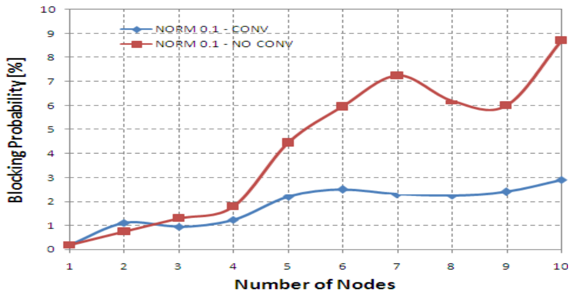

Figure 6: Blocking Probability of Normal Distribution (mean = 0.1) based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations withand without conversion

Fig. 6 shows the blocking probability of normal distribution, with a mean of 0.1, based random assignment models for assignment with (NORM 0.1-CONV) and without wavelength conversion (NORM 0.1-NO CONV). The blocking probabilities are better in the case with conversion assignment beyond node 2. The NORM 0.1-CONV yielded best performance for the node 9 with blocking probabilities of 2.4% and second best for nodes 8 and 10 with blocking probabilities of 2.25 and 2.9% among all other models.

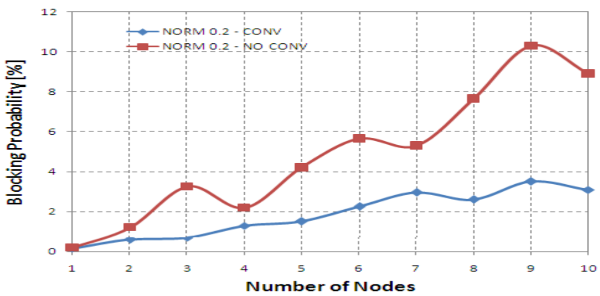

Figure 7: Blocking Probability of Normal Distribution (mean = 0.2) based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and without conversion

Fig. 7 shows the blocking probability of normal distribution, with a mean of 0.2, based random assignment models for assignment with (NORM 0.2-CONV) and without wavelength conversion (NORM 0.2-NO CONV). The NORM 0.2-CONV yielded best performance for the node 4 with blocking probabilities of 1.3% and second best for nodes 2, 3 and 5 with blocking probabilities of 0.6, 0.7 and 1.5% among all other models.

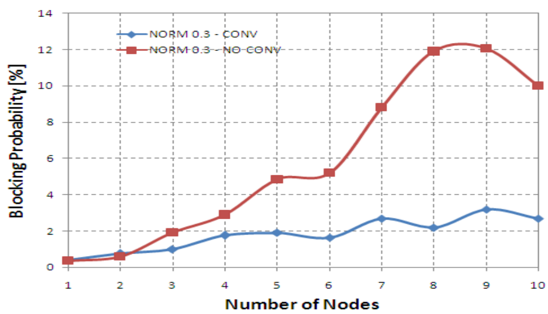

Figure 8: Blocking Probability of Normal Distribution (mean = 0.3) based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and without conversion

Fig. 8 shows the blocking probability of normal distribution, with a mean of 0.3, based random assignment models for assignment with (NORM 0.3-CONV) and without wavelength conversion (NORM 0.3-NO CONV). The NORM 0.3-CONV yielded best performance for the nodes 8 and 10 with blocking probabilities of 2.2 and 2.7% and second best for node 6 with blocking probabilities of 1.65% among all other models.

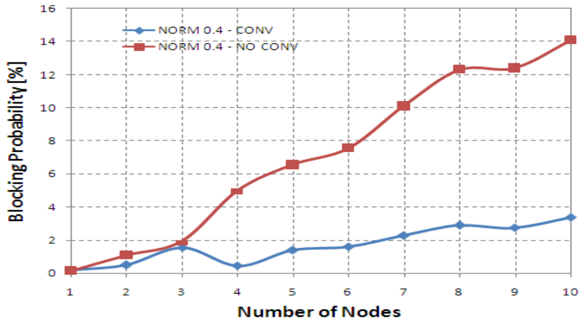

Figure 9: Blocking Probability of Normal Distribution (mean = 0.4) based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and without conversion

Fig. 9 shows the blocking probability of normal distribution, with a mean of 0.4, based random assignment models for assignment with (NORM 0.4-CONV) and without wavelength conversion (NORM 0.4-NO CONV). The NORM 0.4-CONV yielded best performance for the nodes 2, 5 and 6 with blocking probabilities of 0.5, 1.4 and 1.6 % and second best for node 1 with blocking probabilities of 0.2% among all other models.

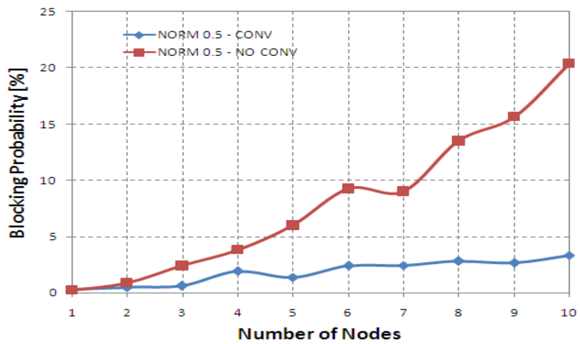

Figure 10: Blocking Probability of Normal Distribution (mean = 0.5) based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations with and without conversion

Fig. 10 shows the blocking probability of normal distribution, with a mean of 0.5, based random assignment models for assignment with (NORM 0.5-CONV) and without wavelength conversion (NORM 0.5-NO CONV). The NORM 0.5-CONV yielded best performance for the nodes 2, 3 and 5 with blocking probabilities of 0.5, 0.6 and 1.4% among all other models.

Table 3: Number of nodes at which the least blocking probabilities are yielded by the models for a tandem network with 10 nodes, 7 channels and 2 Er load

2Er, 10 Nodes, 7 Chan	First Best	Second Best
FIRST FIT - NO CONV	0	0
UNIFORM - NO CONV	0	0
NORM 0.1 - NO CONV	0	0
NORM 0.2 - NO CONV	0	0
NORM 0.3 - NO CONV	0	1
NORM 0.4 - NO CONV	1	0
NORM 0.5 - NO CONV	0	0
FIRST FIT - CONV	0	5
UNIFORM - CONV	1	0
NORM 0.1 - CONV	1	2
NORM 0.2 - CONV	1	3
NORM 0.3 - CONV	2	1
NORM 0.4 - CONV	3	1
NORM 0.5 - CONV	3	0

Table 3 shows the performance summary of the 14 models for the first best and second best predictions. It can be concluded that NORM 04 – CONV model has yield best performance in the prediction for the blocking probabilities at 3 nodes (green) as first best and at one node as second best (yellow). The next model that has yielded good performance is NORM 05 – CONV. Overall, the normal distribution based random assignment of wavelengths with conversion is much better compared to the uniform based random assignment and first fit models in reducing the blocking probabilities of the tandem networks.

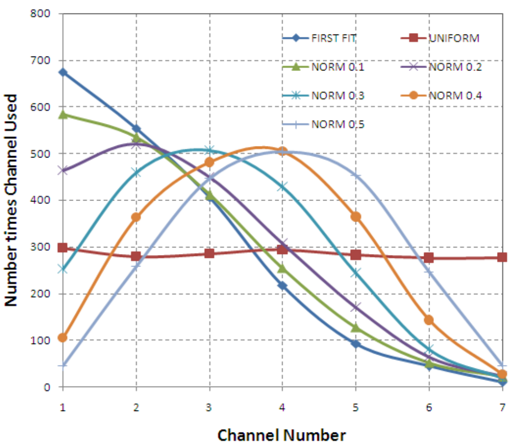

Figure 11: Number of times the channel was used by First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models for a load 2 Erlangs per link and with 10 Nodes, 7 channels and 2000 iterations

Fig. 11 shows the number of times the channel was used by First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models. The models are run for 2000 iterations. Models NORM 0.4 and NORM 0.5 have used the channel 4 maximum number of times, .Models NORM 0.3 and NORM 0.2 have used the channels 3 and 2 maximum number of times respectively. They exhibit the normal distribution pattern in the plot. NORM 0.1 model has the distribution similar to the first fit assignment since NORM 0.1 has used the channel 1 maximum number of times.

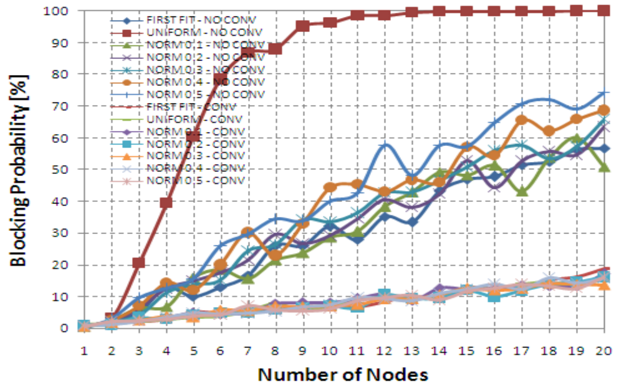

Figure 12: Blocking Probability of First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models for a load 5 Erlangs per link and with 20 Nodes, 11 channels and 2000 iterations with and without conversion

As a second case, a tandem network with higher number of nodes, channels and high load per link is chosen to test the performance of the normal distribution based assignment with wavelength conversion. Blocking Probability of First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models are presented in Fig. 12 for a load 5 Erlangs per link and with 20 Nodes, 11 channels. The iterations were run for 2000 times with and without conversion. As the number of nodes increased, the blocking probabilities also increase. The blocking probability increased to almost 100% when the channels were assigned randomly based on random distribution. It can be concluded from Fig. 12 that when assignments were made with no conversion of wavelengths, the blocking probabilities were above 50% at node 20, whereas, it is less than 20% when conversion was considered.

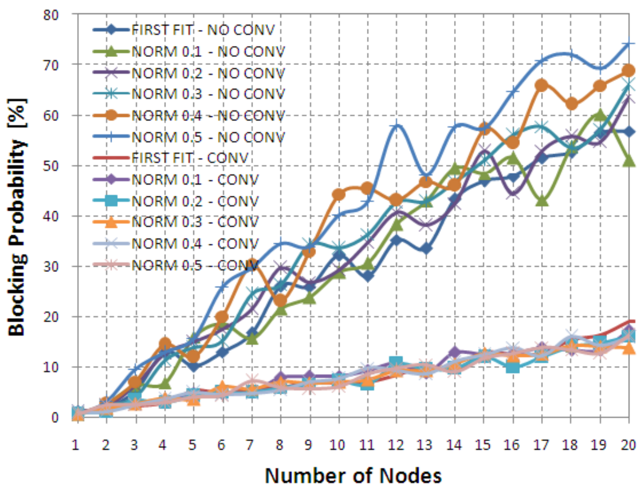

Figure 13: Blocking Probability of First Fit and 5 Normal Distribution based Random Assignment models for a load 5 Erlangs per link and with 20 Nodes, 11 channels and 2000 iterations with and without conversion

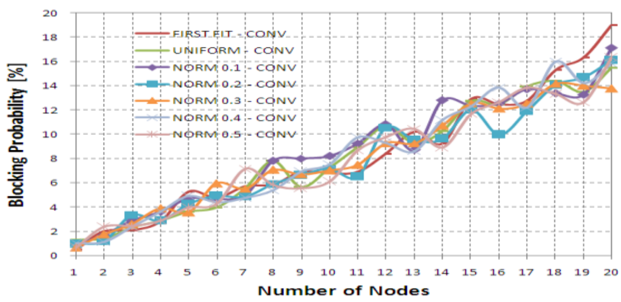

Figure 14: Blocking Probability of First Fit, Uniform Distribution based and 5 Normal Distribution based Random Assignment models for a load 5 Erlangs per link and with 20 Nodes, 11 channels and 2000 iterations with conversion

From Fig. 14, it can be observed that the first fit assignment yield a blocking performance of 19% at node 20 and NORM 0.3 yields 13.75% of blocking probability.

Table 4 lists the blocking probabilities for the case of 5 Erlangs load per link, 20 nodes and 11 channels per link. In Table 4, the least blocking probabilities for each node is marked in red, and the second least blocking probabilities are marked in yellow.

Table 4: Total blocking probabilities [%] of the 20 nodes

5 Er, 20 Nodes, 11 Chan	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
FIRST FIT - NO CONV	1	2.05	5.2	12.85	10.1	12.95	16.65	26	25.9	32.1
UNIFORM - NO CONV	0.8	3.15	20.5	39.4	60.25	78.45	86.75	87.85	95.1	96.2
NORM 0.1 - NO CONV	0.65	2.55	6.3	6.8	15.9	18.6	15.7	21.4	23.7	28.75
NORM 0.2 - NO CONV	1	2.1	6.35	12.55	14.9	17.5	21.45	29.55	26.8	29.15
NORM 0.3 - NO CONV	0.35	2.25	4.05	11.2	13.75	15.1	24.45	26.3	34.15	33.55
NORM 0.4 - NO CONV	0.6	2.6	7.05	14.35	12	20	30.15	23	32.95	44.25
NORM 0.5 - NO CONV	0.4	3.15	9.55	12.8	15.6	25.9	29.75	34.35	33.8	40.1
FIRST FIT - CONV	0.5	2	2.1	2.8	5.25	4.75	5.7	5.85	6.9	6.8
UNIFORM - CONV	1.3	1.4	2.3	2.85	3.6	3.95	5.55	7.8	5.65	7.25
NORM 0.1 - CONV	0.95	1.7	2.9	3.6	4.7	4.65	4.95	7.8	8	8.2
NORM 0.2 - CONV	0.95	1.15	3.35	2.85	4.25	4.9	4.85	5.9	6.6	7.15
NORM 0.3 - CONV	0.65	1.75	2.6	3.9	3.55	5.95	5.5	7.05	6.7	7
NORM 0.4 - CONV	1	1.1	2.35	3.6	4.9	4.4	4.75	5.4	6.9	7.55
NORM 0.5 - CONV	0.65	2.35	2.45	2.9	3.95	4.25	7.15	5.8	5.55	6.1

5 Er, 20 Nodes, 11 Chan	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20
FIRST FIT - NO CONV	28	35.2	33.45	43.25	46.9	47.8	51.45	52.6	56.45	56.75
UNIFORM - NO CONV	98.4	98.5	99.45	99.7	99.8	99.85	99.9	99.85	100	99.95
NORM 0.1 - NO CONV	30.5	38.3	42.9	49.3	48.35	51.4	43.15	53.7	60	50.9
NORM 0.2 - NO CONV	34.65	40.55	38.1	42.45	52.75	44.3	52.9	55.75	54.6	63.4
NORM 0.3 - NO CONV	36.3	42.7	42.85	46.65	50.95	55.95	57.65	53.4	57.2	65.95
NORM 0.4 - NO CONV	45.3	43.1	46.75	45.95	57.1	54.35	65.65	62.1	65.85	68.6
NORM 0.5 - NO CONV	42.75	57.75	48.1	57.65	57.35	64.7	70.85	71.95	69.2	74.15
FIRST FIT - CONV	6.9	8.4	10.2	9.25	12.9	12.45	12.75	15.3	16.3	19
UNIFORM - CONV	8.95	10.65	9.3	10.25	12.75	12.45	13.95	14.4	13.5	15.45
NORM 0.1 - CONV	9.25	10.8	8.7	12.8	12.35	12.55	13.7	13.35	13.25	17.1
NORM 0.2 - CONV	6.5	10.55	9.5	9.6	12	9.95	11.9	14.05	14.65	16.1
NORM 0.3 - CONV	7.45	9.25	9.25	10.7	12.55	12.1	12.5	14.15	14	13.75
NORM 0.4 - CONV	9.75	9.3	8.6	11.15	12.3	13.85	12.2	16	14.2	15.8
NORM 0.5 - CONV	8.65	9.75	10.45	8.9	11.65	12.65	13.85	13.3	12.65	16.3

Table 5: Number of nodes at which the least blocking probabilities are yielded by the models for a tandem network with 20 nodes, 11 channels and 5 Er load

5 Er, 20 Nodes, 11 Chan	First Best	Second Best
FIRST FIT - NO CONV	0	0
UNIFORM - NO CONV	0	0
NORM 0.1 - NO CONV	0	0
NORM 0.2 - NO CONV	0	0
NORM 0.3 - NO CONV	1	0
NORM 0.4 - NO CONV	0	0
NORM 0.5 - NO CONV	0	1
FIRST FIT - CONV	3	3
UNIFORM - CONV	1	3
NORM 0.1 - CONV	0	2
NORM 0.2 - CONV	3	3
NORM 0.3 - CONV	2	2
NORM 0.4 - CONV	4	1
NORM 0.5 - CONV	6	3

Table 5 presents the summary of the performance of the 14 models for number nodes where the least blocking performance was yielded. The first best performance is marked in green and the second best performance is marked in yellow. NORM 0.5 has yielded green at 6 nodes and yellow at 3 nodes, which is the best performance among all the 14 models. The second best is NORM 0.4 with 4 in green and 2 in yellow.

4. CONCLUSIONS

In this work, the wavelength assignment was carried out using two approaches. One with no conversion of the wavelength and, the other with the conversion of the wavelength. A total of 14 models are run for the simulations. Out of 14 models, 7 corresponds to no conversion and the remaining 7 models corresponds to conversion of wavelength for the assignment. The normal distribution based wavelength assignment with wavelength conversion yields the best performance compared to all other conversion models as well as no conversion models. NORM 0.5 model has yielded least blocking probabilities at 6 nodes and next least blocking probabilities at 3 nodes. Whereas the NORM 0.4 model has yielded least blocking probabilities at 4 nodes and next least blocking probabilities at 1 node. The first fit and uniform distribution random assignment with conversion of wavelengths yielded least blocking probability at 3 nodes and 1 node respectively. Overall, the NORM 0.5 is the best model for the tandem network chosen with 20 links, 11 channels with 5 Er load. In case of the tandem network model with 10 links, 7 channels with 2 Er load, NORM 0.4 yielded best results. It can be concluded that least blocking probabilities for majority of the nodes are yielded by the normal distribution based random assignment. Also, the second least blocking probabilities for majority of the nodes are yielded by the normal distribution based random assignment again.

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